With the Compliments of
WM. RIPLEY NICHOLS.

From the Report of the Superintendent of Sewers, Boston. 1879.

Chemical Examinations

OF

SEWER AIR.

BY

PROFESSOR WM. RIPLEY NICHOLS,
Of the Mass. Institute of Technology.

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No. 39 ARCH STREET.
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CHEMICAL EXAMINATION OF THE AIR OF THE SEWER IN BERKELEY STREET, BOSTON, MASS.

W. H. Bradley, Esq., *Superintendent of Sewers:* —

Dear Sir, — In presenting the results of the chemical examinations of "sewer-air" which have been made in my laboratory during the present year, I take the liberty of offering a few general statements with reference to the air in sewers.

When a mixture of organic matter of vegetable and animal origin, such for instance as that which composes ordinary sewage, is allowed to stand, it begins to undergo chemical change, and there are formed, partly by action of atmospheric oxygen and partly by changes taking place within the mass, a great variety of compounds of greater or less complexity and differing in character and relative amount, according to the circumstances under which the decaying matter is placed. Some of the compounds thus formed are gaseous and escape into the surrounding atmosphere. If there is a free circulation of air about the decaying substance, the gaseous products of decomposition may be diluted to such an extent that we cannot appreciate, even by chemical analysis, variations from the normal condition due either to the loss of oxygen used up in the process of decay, or to the addition of foreign ingredients. If, however, the decomposing mass is so situated as to only partly fill a receptacle which contains in addition a limited amount of air, and to which fresh air does not have free access, then a very large proportion of the oxygen of the confined air disappears and the space above becomes filled with the gases which have been produced as a result of decay, in addition to what nitrogen of the air remains. This happens sometimes in closed cesspools or in unventilated drains, when the refuse matter is allowed to accumulate, but it is quite exceptional. In ordinary cesspools or vaults, and in even ill-constructed sewers, there is always some access of air, and the gaseous products of decomposition become more or less diluted so that, although the air in the sewer may seem very foul the devia-

tion from the normal air when expressed in figures is ordinarily quite small.

The principal gaseous products of decay are carbonic acid, marsh gas, and other compounds of carbon and hydrogen, ammonia, together with carbonate and sulphide of ammonium, sulphuretted hydrogen, nitrogen, and carbonic oxide. Some of these gases are actually poisonous, and, if breathed in sufficient quantity, may prove fatal. There are a number of cases on record where men have been seriously affected, and in some cases killed, when undertaking to clean out vaults or cesspools in which these gases of decomposition had accumulated. No one of these substances, however, is of a character to account for the "filth diseases" which are believed to be caused or favored, by breathing the emanations from drains or sewers, nor indeed do we know of any gaseous substance which is capable of producing these effects. As to what the deleterious agent really is we are ignorant. Some consider it to reside in the decomposing organic matter, which, as minute solid particles or as vapor, exists in the foul air; of the nature of these organic matters we are almost entirely ignorant, and we are at present unable to estimate their amount. Others believe the dangerous substances to be actual spores or germs of microscopic vegetable or animal organisms, which, under certain conditions, are capable of producing specific diseases. The weight of such evidence as may be considered experimental is decidedly in favor of the idea that the noxious substances are either minute solid particles or else particles of vapor, and that they are not actually gaseous. Whatever may be the true view of the matter, it is almost universally agreed that the injurious products of decay which rise into the air become innocuous if sufficiently diluted with fresh air.

As we are ignorant of the exact substance to which the bad effects of sewer-air are to be ascribed, it is evident that neither chemical nor microscopical examination can give us the data for asserting whether a certain specimen of air is dangerous or not, — so that chemists must, for the present at least, content themselves with determining how far the air varies from the normal standard, thus obtaining indications of the extent to which the mixture with fresh air is effected, or if it is a case of the air in sewers, of the efficiency of the ventilation.

The term "sewer gas" is an unfortunate one, and gives rise to a quite wide-spread but very erroneous idea. Many seem to suppose the "sewer-gas" to be a distinct gaseous substance, which is possessed of marked distinguishing characteristics, which fills the ordinary sewers and connecting drains, and which, as a tangible something, finds its way through any opening made by chance or by intention, and then, and only then, mixes with the atmospheric air.

It is sometimes alluded to[1] as "a homogeneous mixture of light specific gravity, with immense diffusive power, acting as a distinct body, with its own individual characteristics," and referred to as "soluble in water to such a degree," etc. This idea is utterly erroneous; the gas or air that fills the sewers and issues from them is a continually varying mixture of the gases which make up the atmosphere, mixed with a relatively small proportion of certain other gases which are formed by the decomposition of the sewage, together with aqueous vapor and vapor of organic compounds; this mixture of gases and vapors carries with it, as does also common air, a greater or less amount of minute solid particles held in suspension. As is the case of all gaseous mixtures, each of the various gases diffuses into the surrounding atmosphere independently of the others, and when exposed to water each dissolves according to its own degree of solubility. The organic vapors and solid particles diffuse much less readily, and deposit upon various solid objects, just as in a room which has been occupied by many persons, an offensive odor will cling to the walls and furniture although the air in the room may be thoroughly and repeatedly renewed.

While, with our present state of knowledge, it is impossible to isolate the relatively small amount of noxious matter which exists in the air of sewers and drains, or to say from chemical examination whether any particular specimen of air is dangerous from this cause or not, there is no doubt that the air which comes from the sewers and drains brings with it something which, under certain circumstances, may be the cause of disease, and we should use all means in our power to prevent the entrance of such air into our

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1 E. B. Ellice-Clark, Proc. Assoc. Municipal and Sanitary Engineers I. (1873-74, page 52.)

houses ; moreover, the sewers and drains themselves should be ventilated to such an extent as to dilute the products of decomposition with the largest possible amount of pure air.

In Table I. are to be found, as being of interest in this connection, a few analyses which have been made of the gases arising from sewage-matter decaying under water. Any one of these mixtures would be inflammable, and mixtures approximately somewhat like these have been found in closed cesspools or vaults, but never in sewers[1] properly so called.

In Table II. will be found such examinations of sewer-air as I have been able to put my hands upon. No doubt many other isolated examinations have been recorded, but such analyses are generally made for local Boards, and fail to become accessible to the general public.

In Tables III. and IV. will be found the results of the examinations which it is the main object of this report to present, — namely, those made during the past year on air taken from the Berkeley-street sewer.

This is a six-foot brick sewer which empties into the Charles river, and is so located that by the automatic closing of tide-gates the sewage at certain stages of the tide remains ponded or stored in the sewer ; in times of heavy rains the sewer may be completely filled for a number of hours in succession.

The sewer is about 3,500 feet long, including its upper and smaller levels, and of the man-holes (which occur at intervals of 300 feet) four are provided with perforated covers, all the openings having a combined area of 215 square inches. My experiments were begun at a time when, for other reasons, the water was kept by pumping at a constant low level, the sewage being only a few inches in depth. The pump was inserted in one of the man-holes, the cover of which was removed for the purpose, at a point some twelve hundred feet from that at which the samples of air were taken. During the continuance of the pumping (for some 52 days) samples of air were examined, as a rule, twice a day, and

[1] In the case of sewers it sometimes happens that illuminating gas may leak into them in quantities large enough to form an explosive mixture. This has been the occasion of severe accidents. Other than from this cause, however, the sewer-air never contains more than an extremely small proportion of inflammable gas: sewer-air is neither inflammable nor explosive.

since the pumping has been discontinued, examinations have been made from time to time, as recorded in the tables.

Preliminary examinations showed that the amount of sulphuretted hydrogen, and other foreign gases, was too small to be practically determinable, and it became evident that the most satisfactory results would be arrived at by making numerous determinations of the amount of carbonic acid present under different conditions. Determinations of the amount of oxygen have also been made in a number of cases, and the results are recorded in Table III.

The air from the sewer was conducted into the laboratory by an enameled iron pipe, the entire length being some 400 feet. I satisfied myself, by experiment, that the joints of the pipe were tight, and that the air which remained in the pipe during the progress of a determination was not sensibly affected by the pipe. Of course, before any determination was made, the pipe was thoroughly cleared of the air which had lain stagnant in it.

During the greater portion of the time in which these experiments were carried on, record was made of the direction of the wind, height of barometer, etc.; but it was not possible to discover any direct connection between the data obtained and the variations of the air in the sewer. On this account, the greater part of these observations has been omitted from the tables. It will be observed, however, that in a general way the amount of carbonic acid is greater in the hotter than in the cooler months; thus the average of

31	determinations	in January	was 8.65	vols. of	carbonic acid	in 10,000	vols.	of air.
44	"	February	" 8.16	"	"	"	"	"
47	"	March	" 11.53	"	"	"	"	"
12	"	April	" 10.75	"	"	"	"	"
8	"	June	" 27.52	"	"	"	"	"
8	"	July	" 21.92	"	"	"	"	"
6	"	August	" 23.95	"	"	"	"	"

It appears from these examinations that in such a sewer as the one in Berkeley street, which, being of necessity tide-locked, is an example of the worst type of construction, the air does not differ from the normal standard as much as many, no doubt, suppose. In a general way, as we have seen, there is a larger amount of variation from normal air during the warmer season of the year;

but even when the amount of carbonic acid was largest, it was only extremely seldom that sulphuretted hydrogen could be detected, by employing for the purpose even a considerable amount of the sewer air. Sulphuretted hydrogen and other gases of decomposition exist at times, perhaps always, in the sewer: articles of lead or copper become coated with the sulphides of these metals if exposed for some time; but in this sewer I have never found enough to determine and to express in figures.

While I am a thorough believer in and advocate of sewer-ventilation, and of the exclusion of sewer-air from our houses, I think it should be said that the soil-pipes and house-drains are much more likely causes of discomfort and danger than the sewers. Moreover, it is to be borne in mind that there is a strong desire at the present day to ascertain the exact cause of existing sickness, especially in the case of certain diseases; it is a question whether sometimes the sewer (or the water supply) is not made to bear the burden of charges for which there is no sufficient proof.

Whether the air in the sewer will be appreciably improved when, by the new system of sewerage, a constant flow is maintained so that the sewage is never allowed to accumulate, is uncertain. After the pumping stopped last spring, it appeared for a time that the amount of carbonic acid increased; but as the amount varies considerably from time to time when no pumping is going on, it would not be possible to assert that the pumping really produced any effect. I hope to make some examinations this winter and in the coming spring, to compare with those made last February; we may then have better grounds for drawing conclusions. I fear, however, that satisfactory results could be reached only by repeating the pumping experiment, at different seasons of the year, and examining the air before and after as well as during the time of the pumping.

All of the analytical determinations recorded in the Tables III. and IV. were made by my assistant, Mr. Thomas F. Stimpson, S.B., my indebtedness to whom I take pleasure in acknowledging.

WM. RIPLEY NICHOLS.

Mass. Institute of Technology, Dec. 1, 1878.

TABLE I.—*Examination of Gases from Decomposing Sewage-Matter.*

[Results expressed in percentages.]

Authority.	Marsh Gas. (CH_4)	Carbonic oxide (CO)	Carbonic acid. (CO_2)	Sulphuretted Hydrogen. (SH_2)	Nitrogen.	
R. Angus Smith..........	88.81	....	5.84	....	5.35	Gases evolved from sewage-matter in the Medlock (Eng.) (R. Angus Smith, Disinfectants and Disinfection. Edinburgh, 1869, p. 25.)
Dr. Letheby.............	73.83	....	15.90	0.08	10.19	Gases evolved from sewage decomposing in the absence of air. (Quoted from Parkes' Hygiene, p. 103.)
Durand-Claye	72.88	2.54	13.30	6.70	4.58[1]	Gases evolved by decomposing sewage mud in the Seine. (Assainissement de la Seine, Paris, 1876. Deuxième partie. Annexes, p. 85.)

[1] And other gases.

TABLE II. — *Examination of Sewer-Air.*

[Results expressed in percentages.]

Date.	Authority.	Locality.	Oxygen.	Nitrogen.	Carbonic Acid.	Sulphuretted Hydrogen.	Marsh gas. (CH_4)	Ammonia.	
182(?)	Gaultier de Claubry . .	Paris	13.79	81.21	2.01	2.99	. . . .	. . . .	Air in a choked sewer. (Quoted from Parent-Duchâtelet, "Essai sur les cloaques," Paris, 1824, p. 223.)
1829	Gaultier de Claubry . .	Paris	17.4	. . . .	. . . .	. . . .	. . . .	. . . .	Smallest amount in any one of the 19 samples examined.
					3.4	. . . .	. . . .	. . . .	Largest amount " " " " " " "
						1.25	. . . .	. . . .	" " " " " " " " "
					2 3	0.81	. . . .	. . . .	Mean amount in 19 samples.
									(Quoted from Parkes' Hygiene, p. 104.)
1858	Dr. Letheby	London	19.51	79.96	0.53	traces.	traces.	more than traces.	(Quoted from Parkes' Hygiene, p. 104. Latham, San. Engineering, p. 205.)
1867	Dr. W. A. Miller . . .	London	. . . .	. . . .	0.11	. . . .	. . . .	. . . .	Mean of 18 samples. Sewer without charcoal ventilators.
			20.71	. . . .		. . . .	. . . .	. . . .	" " 6 " " " " "
			20.79	. . . .	0.13	0	. . . .	. . . .	" " 7 " " with " "
					0.31	. . . .	. . . .	. . . .	" " 6 " (another sewer) without " "
					0.25	. . . .	. . . .	. . . .	" " 24 " " " with " "
			20.70	. . . .	. . . .	0	. . . .	. . . .	" " 4 " " " " " "
									(Quoted from Chemical News XVII (1868), p. 156.)
1870	Dr. W. J. Russell	Paddington, London .	20.79 ~~[illegible]~~	78.81 ~~[illegible]~~	0.40 ~~[illegible]~~	. . . .	. . . .	traces.	(Quoted from ~~Parkes' Hygiene, p. 104.~~) Br. Assoc. Rep. 1870.
1871	J. J. Nicholson	Sunderland, Eng. . .	18.44	81.10	0.55	traces.	. . .	traces	(Quoted from Proc. Munic. & San. Engineers, I (1873-74), p. 50.)
1873	" "	" " . .	19.33	80.35	0.23	. . . .	. . . .		
1876	Drs. Wolffhügel & Bleetz.	Munich	*	. . . .	0.33	. . . .	. . . .	. . . .	Mean of sewer examinations in three sewers.
			*	. . . .	0.40	. . . .	. . . .	. . . .	Maximum of " " " " "
									(Quoted from II Bericht der Commission für Wasserversorgung, etc., Munich, 1877, p. 50.)

* Not essentially different from ordinary air.

TABLE III. — *Composition of the Air of the Berkeley-street Sewer.*

No.	Date.	Per cent. of Oxygen.	Per cent. of Nitrogen.	Per cent. of Carbonic Acid.	Ratio of Oxygen to Nitrogen.
	Normal Air (about)	20.96	79.00	.04	1 : 3.769
26*	January 29, 11.30 A.M.	20.86	79.09	.05	1 : 3.792
27*	" 29, 2.15 P.M.	20 76	79.13	.11	1 : 3.812
33*	February 1, 2.15 "	20.81	79.03	.16	1 : 3.798
92*	March 8, 9.10 A.M.	20.90	78.97	.13	1 : 3.778
96	" 11, 9.25 "	20 82	79.12	.06	1 : 3.801
102	" 14, 9.40 "	20.71	79.12	.17	1 : 3.819
108	" 19, 10 40 "	20.48	79.26	.26	1 : 3.871
117	" 23, 10.00 "	20.72	79.12	.16	1 : 3.819
124	" 28, 9.40 "	20 78	79.04	.18	1 : 3.803
140	June 21, 2.30 P.M.	20.63	79.05	.32	1 : 3.832
141	" 24, 9.45 A.M.	20.68	79.10	.22	1 : 3.825
142	" 24, 2.00 P.M.	20.62	78.98	.40	1 : 3.830
143	" 25, 3.15 "	20.69	79.03	.28	1 : 3.820
144	" 26, 3 30 "	20 78	79.06	.16	1 : 3.805
145	" 27, 3.20 "	20.75	78.89	.36	1 : 3.802
146	" 28, 2.30 "	20.72	79.10	.18	1 : 3.818
147	" 29, 3.00 "	20.77	78.96	.27	1 : 3.802
148	July 18, 2.00 "	20.87	78.98	.15	1 : 3.784
149	" 19, 10.45 A.M.	20.73	78.97	.30	1 : 3.809
150	" 19, 2.30 P.M.	20.84	78.98	.18	1 : 3.790
151	" 20, 1.45 "	20.76	78.95	.29	1 : 3.803
152	" 22, 10.15 A.M.	20.88	79.02	.10	1 : 3.785
153	" 22, 3.10 "	20.72	79.03	.25	1 : 3.814
154	" 23, 2.15 "	20.74	79.01	.25	1 : 3.810
155	" 24, 2.00 "	20.71	79.04	.25	1 : 3.817

* The sewage was kept running freely all the time, by pumping, from Jan. 17th to March 9th, — afterwards the sewer was tide locked, discharging twice a day.

Table IV. — *Amount of Carbonic Acid in the Air of the Berkeley-street Sewer.*

No.	Date. — 1878.		Hour.	Approx. time in hours before (—) or after (+) high tide.	Volumes of Carbonic Acid in 10,000 volumes of air.	Height of Barometer.
1	January	17[2]	....	....	8.4	
2	"	18	9 A.M.	— 2	8.1	
3	"	18	10 "	— 1	8.1	
4	"	18	2 P.M	+ 3	11.2	
5	"	18	3.15 "	+ 4¼	10.0	
6	"	18	4.15 "	+ 5¼	8.2	
7	"	19	2.30 "	+ 2½	10.2	
8	"	19	4 "	+ 4	12.8	
9	"	21	10.30 A.M.	— 2¾	12.0	
10	"	21	11.15 "	— 2	12.0	
11	"	21	1.45 P.M.	+ ½	9.4	
12	"	21	3 "	+ 1¾	12.8	
13	"	23	1.15 "	— 1½	7.0	
14	"	23	2.30 "	— ¼	8.5	
15	"	23	3.45 "	+ 1	8.3	
16	"	24	9.45 A.M.	— 5¾	2.5	
17	"	24	11 "	— 4½	3.8	
18	"	24	3 P.M.	— ½	5.3	
19	"	25	3.15 "	— 1	9.8	
20	"	25	4.25 "	0	13 0	
21	"	26	11.45 A.M.	— 5½	8.8	29.92
22	"	26	3.25 P.M.	— 1¾	10.5	29.91
23	"	28	2 "	— 5½	7.1	29.60
24	"	28	3 "	— 4½	9.1	29.63
25	"	29	10 A.M.	+ 1½	8.7	30.15
26	"	29	11.30 "	+ 3	5.3	30.14
27	"	29	2.15 P.M.	+ 5¾	10.6	30.22
28	"	29	3.40 "	— 4¾	7.1	30.20
29	"	30	10.30 A.M.	+ 1	6.2	30.55
30	"	30	3 P.M.	+ 5½	6.7	30.56
31	"	31	11 A.M.	+ ½	6.9	30.44
32	February	1	12 M.	+ 1	8 8	29.88
33	"	1	2.15 P.M.	+ 3½	15.6	29.92

[1] The outer air has from 2.5 to 4.0 volumes in 10,000.

[2] From this date to March 9th, the sewage was pumped so as to produce a continuous flow.

TABLE IV. — *Continued.*

No.	Date. — 1878.	Hour.	Approx. time in hours before (—) or after (+) high tide.	Volumes of Carbonic Acid in 10,000 volumes of air.	Height of Barometer.
34	February 2	10 A.M.	— 1¾	10.0	30.26
35	" 2	3.30 P.M.	+ 3¾	10.0	30.26
36	" 4	10.45 A.M.	— 1¾	6.0	29.98
37	" 4	3.45 P.M.	+ 3¼	8.3	29.92
38	" 5	10.30 A.M.	— 2¾	7.1	30.02
39	" 5	2.30 P.M.	+ 1¼	11.2	30.00
40	" 6	11 A.M.	— 2¾	8.5	30.21
42	" 7	9.45 "	— 4¾	8.8	30.13
43	" 7	2.15 P.M.	— ¼	6.7	30.06
44	" 8	9.30 A.M.	— 5½	9.8	29.95
45	" 8	1.30 P.M.	— 1½	6.9	29.84
46	" 9	11.30 A.M.	— 4¼	5.4	29.75
47	" 11	9.30 "	+ 4	8.3	29.72
48	" 11	2.30 P.M.	— 3	5.4	29.77
49	" 12	9.30 A.M.	+ 3	7.2	30.08
50	" 12	1.30 P.M.	— 5	8.1	30.02
51	" 13	9.30 A.M.	+ 1¾	6-2	29.97
52	" 13	1.45 P.M.	+ 6	8.2	29.91
53	" 14	10.45 A.M.	+ 2	8.4	30.15
54	" 14	2.00 P.M.	+ 5	7 4	30.12
55	" 15	10.40 A.M.	+ ¾	6.8	30.16
56	" 15	2.00 P.M.	+ 4	9.5	30.12
57	" 16	10.30 A.M.	— ¼	9.2	30.07
58	" 16	1.45 P.M.	+ 3	12.3	30.03
59	" 18	9.15 A.M.	— 2¾	7.1	30.02
60	" 18	1.35 P.M.	+ 1½	6.5	30.01
61	" 18	3.00 "	+ 3	6.3	30.04
62	" 19	9.25 A.M.	— 3¼	7.6	30.32
63	" 19	1.20 "	+ ½	7.3	30.28
65	" 20	2.00 P.M.	+ ½	9.3	30.22
66	" 21	9.30 A.M.	— 4¾	10.2	30.20
67	" 21	3.00 P.M.	+ ¾	11.4	30.25
68	" 22	11.15 A.M.	— 3¾	7.4	30.20
69	" 23	9.30 "	+ 5¼	6.6	29.90
70	" 23	2.45 P.M.	— 1	10.3	29.89
71	" 25	9.30 A.M.	+ 3½	5.3	29.94

TABLE IV. — *Continued.*

No.	Date. — 1878.		Hour.	Approx. time in hours before (—) or after (+) high tide.	Volumes of Carbonic Acid in 10,000 volumes of air.	Height of Barometer.
72	February	25	1.45 P.M.	— 4¼	6.3	29.88
73	"	26	10.00 A.M.	+ 2¾	7.4	29.91
74	"	26	1.30 P.M.	— 5¾	6.0	29.90
75	"	27	9.30 A.M.	+ 1½	7.5	30.02
76	"	27	3 00 P.M.	— 5¼	7.6	29.94
77	"	28	10.30 A.M.	+ 1¼	9.2	30.02
78	March	1	1.45 P.M.	+ 3¾	6.4	30.56
79	"	2	11.00 A.M.	+ ½	7.5	30.37
80	"	2	2.15 P.M.	+ 3¾	16.5	30.25
81	"	4	9.20 A.M.	— 2½	11.1	29.39
82	"	4	1.30 P.M.	+ 1¾	6.4	29.50
83	"	5	9.10 A.M.	— 3	6.8	30.22
84	"	5	1.30 P.M.	+ 1½	8.9	30.25
86	"	6	9.35 A.M.	— 3	7.4	30.38
88	"	6	1.40 P.M.	+ 1	6.2	30.32
90	"	7	9.20 A.M.	— 4	10.1	30.08
91	"	7	1.50 P.M.	+ ¾	14.7	29.99
92	"	8	9.10 A.M.	— 4½	12.8	30.31
93	"	8	1.35 P.M.	— ¼	9.9	30.32
94	"	9	10.00 A.M.	— 4½	6.1	30.61
95	"	9[1]	1.10 P.M.	— 1¼	7.4	30.57
96	"	11	9.25 A.M.	+ 5½	5.6	30.40
97	"	11	1.25 P.M.	— 2½	6.9	30.40
98	"	12	9.45 A.M.	+ 4¾	8.0	30.40
99	"	12	1.45 P.M.	— 3¼	6.6	30.37
100	"	13	11.00 A.M.	+ 4¾	10 3	29.72
101	"	13	1.45 P.M.	+ 4½	10.6	29.71
102	"	14	9.40 A.M.	+ 2¼	16.9	29.84
103	"	14	1.50 P.M.	— 5½	11.9	29.83
104	"	15	9.30 A.M.	+ 1	13.6	30.07
105	"	15	4.30 P.M.	— 4	13.3	30.07
106	"	16	9.30 A.M.	0	7.9	30.24
107	"	16	1.30 P.M.	+ 4	7.8	30.18
108	"	19	10.40 A.M.	— 1¼	25.5	29.87

[1] Pumping sewer ceased here, and sewage was ponded till low water, twice a day.

TABLE IV. — *Continued.*

No.	Date. — 1878.		Hour.	Approx. time in hours before (+) or after (—) high tide.	Volumes of Carbonic Acid in 10,000 volumes of Air.	Height of Barometer.
109	March	19	4.00 P.M.	+ 4	38.0	29.83
110	"	20	10.40 A.M.	— 1½	12 6	29.85
111	"	20	2.30 P.M.	+ 2¼	21.3	29.87
112	"	21	9.25 A.M.	+ 3½	8.4	30.20
113	"	21	11.00 "	— 2	7.3	30.21
114	"	21	1.30 P.M.	+ ½	7.6	30.18
115	"	22	10.00 A.M.	— 3¾	8.7	30.24
116	"	22	1.30 P.M.	— ½	8.4	30.17
117	"	23	10.00 A.M.	— 4¾	16.0	29.83
118	"	23	1.50 P.M.	— 1	32.0	29.68
119	"	25	9.30 A.M.	+ 5	8.2	29.61
120	"	25	10.50 A.M.	— 5¾	6.8	29.61
121	"	25	1.40 P.M.	— 3	12.9	29.64
122	"	26	10.10 A.M.	+ 4¼	11.4	29.95
123	"	26	1.25 P.M.	— 4¼	15.7	29.96
124	"	28	9.40 A.M.	+ 2	17.7	29.81
125	"	28	2.00 P.M.	— 5¾	11.1	29.75
126.	"	30	10.40 A.M.	+ 1¼	7.1	30.18
127	"	30	1.40 P.M.	+ 4¼	7.9	30.13
128	April	1	10.30 A.M.	0	7.4	29.76
129	"	2	10.30 "	— ¾	9.9	29.80
130	"	4	10.30 A.M.	— 1½	8.7	29.72
131	"	6	9.40 "	— 3½	13.2	29.35
132	"	6	1.30 P.M.	0	6.8	29.34
133	"	20	10 00 A.M.	— 3½	8.0	30.06
134	"	20	1.30 P.M.	0	13.7	29.95
135	"	22	1.30 "	— 2	20.3	30.10
136	"	23	1.25 "	— 3	10.3	29.95
137	"	24	1.40 "	— 3½	8.0	30.10
138	"	25	1.25 "	— 4¾	9.6	29.95
139	"	26	1.15 "	— 5¾	13.2	29.95
140	June	21	2.30 "	— 1¼	32.1	29.95
141	"	24	9.45 A.M.	+ 3¾	22.3	29.95
142	"	24	2.00 P.M.	— 4	40.2	29.90
143	"	25	3.15 "	— 3¾	28.0	29.86
144	"	26	3.30 "	— 4¼	16.4	29.95

TABLE IV. — *Continued.*

No.	Date.		Hour.	Approx. time in hours before (—) or after (+) high tide.	Volume of Carbonic Acid in 10,-000 volumes of Air.	Height of Barometer.
145	June	27	3.20 P.M.	— 5½	36 4	30.15
146	"	28	2.30 "	+ 4¾	17.8	30.19
147	"	29	3.00 "	+ 4½	27.0	30.22
148	July	18	2.00 "	0	14.5	29.91
149	"	19	10.45 A.M.	— 3¾	30.1	29.96
150	"	19	2.30 P.M.	0	17.7	29.91
151	"	20	1.45 "	— 1¼	29.1	30.19
152	"	22	10.15 A.M.	+ 5¾	9.8	29.65
153	"	22	3.10 P.M.	— 1¼	24.7	29.69
154	"	23	2.15 "	— 3	24.8	30.05
155	"	24	2 00 "	— 4¼	24.7	30.13
156	Aug.	22	10.00 A.M.	+ 4¼	18.1	30.24
157	"	22	2.15 P.M.	— 3¼	22.8	30.48
159	"	24	2.15 "	— 5¾	23.5	30.18
160	"	26	2.00 "	+ 4	16.5	30.10
161	"	27	3.00 "	+ 4¼	32.9	30.10
162	"	28	2.10 "	+ 2½	29.9	30.18

ANALYTICAL NOTE. — The determinations of carbonic acid were made by Pettenkofer's method. By means of a Y-tube and two aspirators, regulated to run at the same rate, the stream of air was divided and drawn through two baryta-tubes, so that each result in the table is a mean obtained from two parallel experiments. The oxygen was determined by absorption with alkaline pyrogallate, using the modified form of Doyère's gas apparatus, described by C. W. Hinman, Amer. Jour. Sci. (3) viii, (1874), page 182. Determinations of the outer air made by this method gave 20.96 per cent. of oxygen as a mean of nine examinations made on different days.

The amounts obtained in the several experiments were as follows: —

21.00	20.96	20.98
20.93	20.97	21.00
20.99	20.91	20.92